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Short window of opportunity for brown bear (*Ursus arctos*) predation on reindeer (*Rangifer tarandus*) calves

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ABSTRACT

To improve and develop a management system for reindeer husbandry regarding minimizing depredation by brown bears, knowledge about current depredation patterns is required. Using data obtained from a predation study regarding brown bear predation on reindeer from 2010 to 2012 I aimed at investigating what solutions are available to minimize brown bear predation on reindeer calves. This study has shown that predation on reindeer calves by brown bears in relation to the dates of birth for the calves in the study area was delayed by approximately one week. It has also shown that bears stopped killing reindeer calves approximately one week after the last calf in the studied herds was born. Mobility of the reindeer calves is assumed to be a determining factor affecting hunting success, since encounters then decrease. The two most feasible ways to minimize predation by brown bears can be to; 1) ensure that there is an adequate proportion of male reindeer in the herds so that all female reindeer are mated during the first rutting period and; 2) to minimize human disturbances during sensitive periods such as the rutting and calving period.

Key words: *Ursus arctos, Rangifer tarandus, predation, management, reindeer husbandry*

INTRODUCTION

Predator-prey dynamics are essential to the understanding of how ecosystems are formed and regarding knowledge about population interactions within ecosystems (Sallan et al. 2011; Dawes & Souza 2013; Montgomery et al. 2014). A growing concern for wildlife managers and conservationists is the widespread issue of the conflict between wildlife and humans (Woodroffe et al. 2005). In all areas where livestock and carnivores co-exists there is, to various degrees, livestock depredation occurring. This is one of the reasons why humans, in illegal or legal ways, constitute the main factor in many parts of the world today affecting the numbers and distribution of large carnivores (Thiel 1985; Mech et al. 1988; Mladenoff et al. 1995; Mace & Waller 1996; Sunde, Snorre & Kvam 1998; Treves & Karanth 2003; Andre´n et al 2006).

One example of a conflict between wildlife and humans is found with the reindeer husbandry in Sweden, where the reason for conflict is that Scandinavian brown bears prey on reindeer (Klein 1980; Nieminen et al. 2011; Karlsson et al. 2012). Between 63 to 100 % of reindeer calves lost between calving and autumn calf branding can be due to bear predation (Karlsson et al. 2012). Reindeer husbandry in Sweden is based on maximizing production and this is obtained by the harvest of adult male reindeers in September and the slaughter of calves later in the autumn (Danell 1999; Lundqvist 2007).

Predation is, together with insect attacks and plant phenology, suggested as the main factors affecting birth synchrony and calving in the *Rangifer* genera (Bergerud, 1975; Skogland, 1989). Bears mainly kill calves of ungulates the first four weeks from their birth (Zager & Beecham 2006; Barber-Meyer et al. 2008). For Scandinavian reindeer this period is early May to early June (Kindberg et al. 2012). This calving period is the window of opportunity for brown bear predation on reindeer calves and most of brown bear predation occurs during this period (Klein 1980; Adams et al. 1995; Zager & Beecham 2006).

Due to the economic loss of reindeer due to predation by carnivores such as brown bear (Danell et al. 2009), an effective management plan for reindeer husbandry is needed to minimize losses and mitigate the conflict between carnivores and humans. As a step in the development of an effective management plan further knowledge is needed on the predator-prey dynamics regarding brown bears and reindeer in Scandinavia. In my study I have been able to study predation patterns of brown bear predation in detail by using GPS technology.

In my study I had four objectives regarding brown bear predation on reindeer calves: 1) Investigate if chase distance varies with the number of days from May 1 when the calving starts; 2) Investigate if the chase distance varies with the size of reindeer calves using the length of metatarsus as a measure for calf size; 3) Investigate if the proportion of successful hunts varies with the number of days from May 1 when the calving starts; and 4) Discuss if it is effective and/or possible to reduce brown bear predation on reindeer calves by narrowing the window of opportunity for predation. To test my objectives I used data collected from an earlier study on brown bear predation on reindeer (Karlsson et al. 2012).

MATERIAL AND METHODS

Study area and study period

The study area consisted of parts of two Swedish Sámi villages with semi-domesticated reindeer herds (Moen & Danell 2003). Udtja and Gällivare Sámi villages are forest dominated areas located in Norrbotten county in northern Sweden. The total study area was 3754 km^2 (Udtja = 1284 km^2, Gällivare = 2470 km^2) and housed approximately 1000 adult female reindeers in each area. The data was collected in 2010-2012.

Data collection

Data was collected during a brown bear predation study that was conducted in 2010-2012 (Karlsson et al. 2012). 24 bears were provided with GPS collars in order to record brown bear predation on reindeer calves. Handling of the bears was carried out according to the protocol for capturing and anesthetizing of brown bears described by Evans et al. (2012). Of the 24 bears provided with collars, 22 bears had a proximity function activated and they were at some point observed within the study area. In total, the study recorded 1479 bear days within the study area.

Bear proximity collars were programmed to take a position every 30 minutes and to search for the reindeers' UHF collar every 8 seconds. This schedule was active between May 1 to September 24 in 2010 and 2011, and May 1 to July 1 in 2012. When a female UHF-collared reindeer and a GPS-collared bear were approximately ≤100 meters from each other the bear's GPS started taking positions every 60 seconds until one hour after the latest contact. GPS positions were sent to computers along with the ID of the reindeer that the bear had been close to. Data was then visualized in GIS software.

Reindeer is classified as a follower species. This means that neonatals stay close to their mother and follow their side during movement (*Lent 1974; Rutberg 1984; Shackleton & Haywood 1985*). This makes it is possible to use the movement patterns for female reindeer to monitor the movements of the calves. During 2010, killed calves were only found in areas where a minimum of 4 positions were recorded within a radius of 30 meters. Thus, during 2011 and 2012, only areas containing a minimum of 3 positions within a radius of 30 meters were visited. This was defined as a cluster. Clusters were not visited before the bear had moved a minimum of 1 kilometer from the cluster in order to avoid disturbance. Visits in the field were conducted by both a researcher and a reindeer herder and together they determined the cause of death, gathered remains of the carcass and took it back to camp for further analysis. The total number of reindeer calves killed by radio-collared bears in this study was 317.

Female reindeers were gathered in spring (March-April) and examined for gestation using ultrasound. Females classified as pregnant were provided with a UHF collar. A total of 1694 females were examined throughout the study period. In 2010, 1000 female reindeer were confirmed pregnant and 990 of these were provided with a UHF collar. In 2011 in Gällivare Sámi village 893 pregnant female reindeers were equipped with UHF collars. During 2011 and 2012 another 245 females were collared with UHF collars in Udtja and 457 in Gällivare adding up to a total of 2585 pregnant female reindeer provided with UHF collars during the study period. The proportion of females that were pregnant in this study was 90 to 95 % which is similar to other studies (Eloranta & Nieminen 1986; Tyler 1987).

In total, 689 encounters (occasions where a bear's GPS collar was activated by the presence of a reindeer UHF collar) were recorded. This resulted in 1283 clusters. Data for calves born was obtained in 2013. Two pens, each housing a maximum of 100 female reindeers, were monitored during the calving season and all birth dates were noted, giving a total of n = 159 calves born.

During cluster visits carcass remains were collected and brought back to camp. A measurement of the metatarsus was taken and I here define the length of the metatarsus as the length from the tip of the hoof to the knee. A total of n = 75 measurements could be performed. The low number, compared to the number of found calves, was due to that not all carcasses contained a measurable metatarsus due to predator handling of the carcass.

Data analysis

For the analysis regarding temporal distribution of the calving period, non-linear regression was used. To investigate if the chase distance changed with the number of days from May 1, or with increased metatarsus length, I used linear regression (XLSTAT) to determine presence or lack of a statistical relationship. Chase distance was defined as the distance from the point where the bear GPS collar first detected a reindeer UHF collar and started taking positions every 60 seconds, to the center of the cluster in which a dead reindeer calf was found. Chase distances were measured using GIS-software (ArcMap 10.2, ESRI). On occasions where the bear's GPS collar was triggered and multiple carcasses were found, the last point for the chase distance was set to the center of the first carcass-containing cluster for that occasion.

I also used linear regression to assess if the number of successful hunts would decrease with the number of days from May 1. Data from all three years were pooled. An occasion where a bear's GPS was triggered by a reindeer UHF collar was considered a successful hunt if a bear-killed reindeer calf was found within a cluster along the chase path. The maximum number of days from May 1 was set to 49 (n=49) since no successful hunts were recorded after that time period and therefore rendered additional days irrelevant to the analysis. 269 of the 689 encounters resulted in a successful hunt (average 24 % successful hunts, 1.2 calves killed per successful hunt, 0.4 killed per hunt).

RESULTS

In the two pens with calving females (n = 159), reindeer calving started May 2, peaked May 15 and stopped at June 1 (R^2 = 0.46). The first of the 317 bear-killed calves was killed May 10 and the number of calves killed per day peaked at 22 on May 21. The last calf was killed on June 9 (R^2 = 0.712). The first record of a bear GPS collar detecting a reindeer UHF collar was May 1, peaking at 49 detections on May 25 (R^2 = 0.684). (Fig. 1)

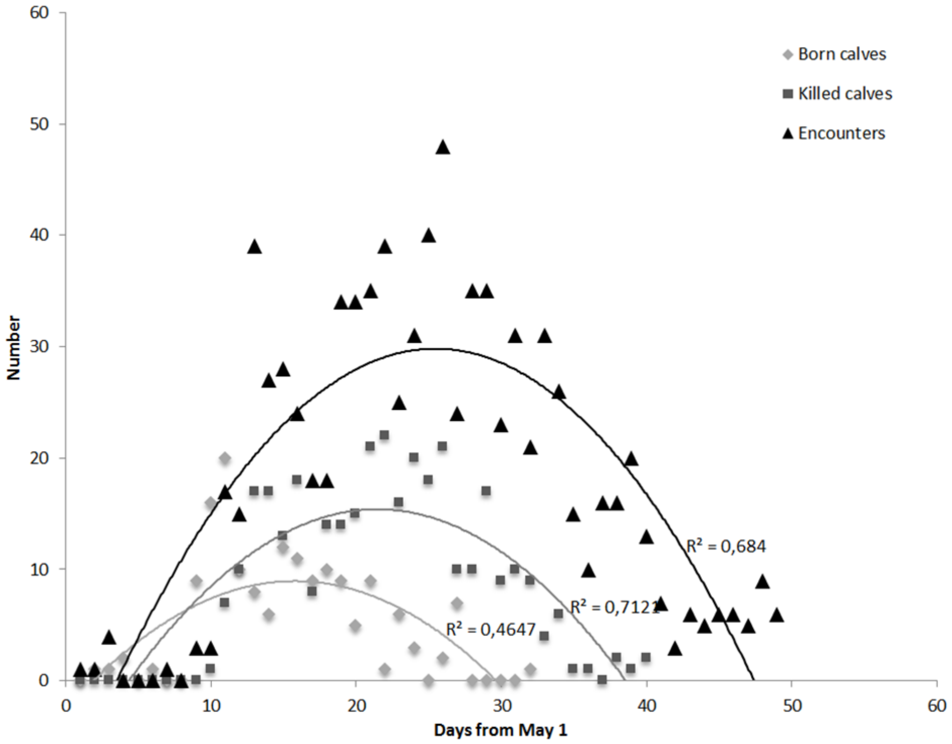

Figure 1: Born calves (R^2 = 0.465, n = 159), killed calves (R^2 = 0.712, n = 317) and occasions where a bear GPS collar detected a reindeer UHF collar (R^2 = 0.684) in relationship to the number of days from May 1.

No significant change in chase distance over time (R^2 = 0.024, p = 0.187, n = 75) was detected (Fig. 2).

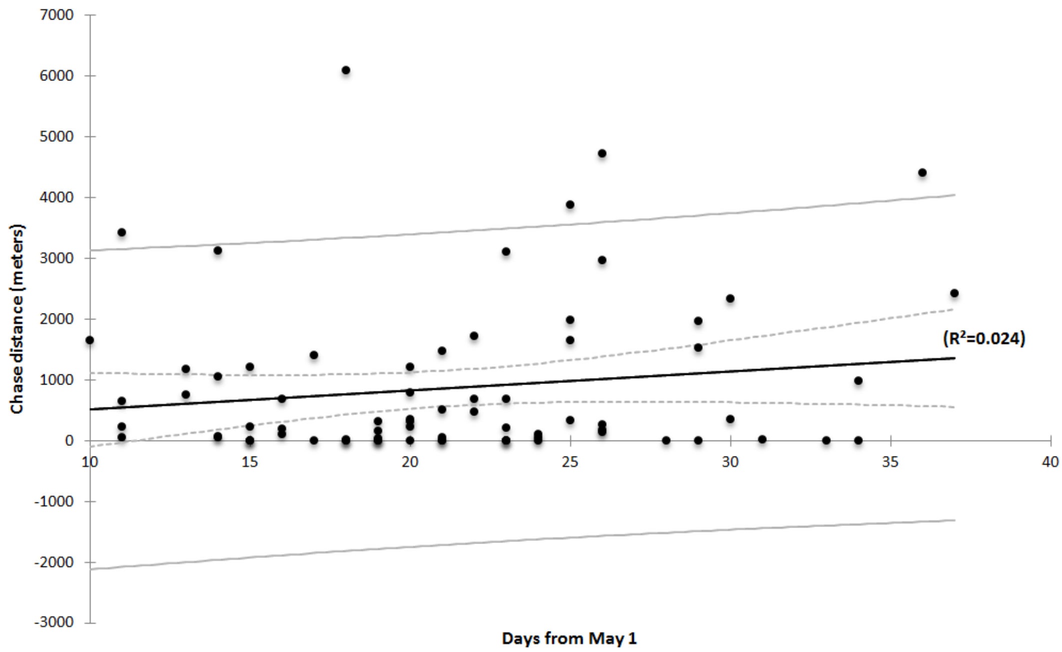

Figure 2: Chase distance shown in relation to number of days from May 1 (R^2 = 0.024, p = 0.187, n = 75).

Chase distance and the length of the metatarsus in reindeer calves (Fig. 3) showed no statistical relationship (R^2 = 0.006, p = 0.517, n = 75).

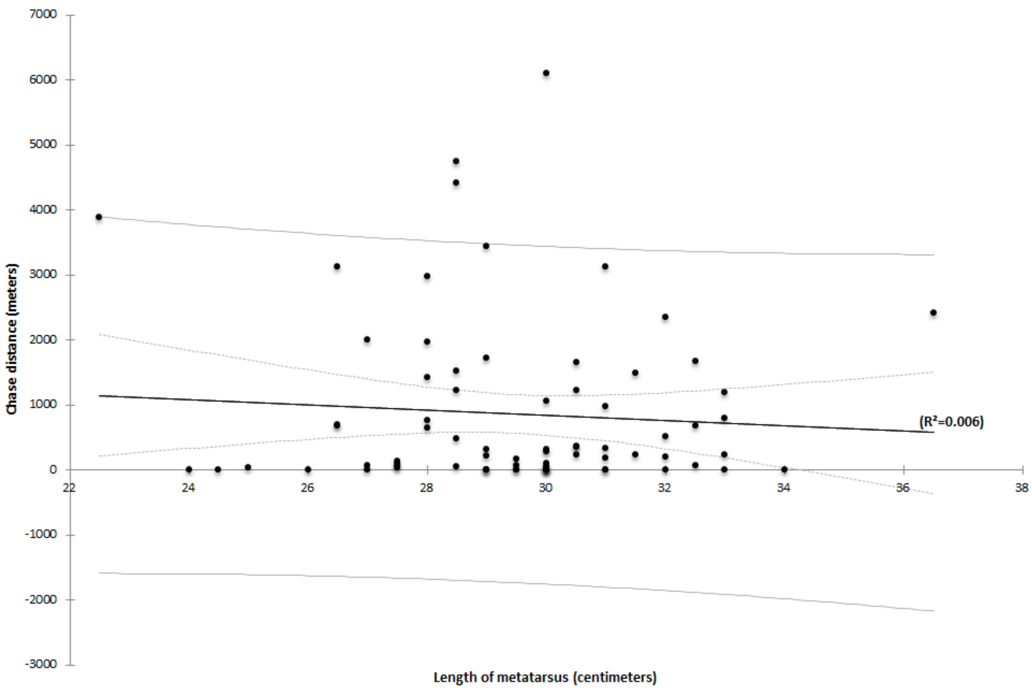

Figure 3: Chase distance (meters) shown in relation to length of the metatarsus (centimeters) in reindeer calves (R^2 = 0.006, p = 0.517, n = 75).

The proportion of successful hunts in relation to days from May 1 was negatively related (R^2 = 0.698, p < 0.0001, n = 40), (Fig. 4). I analyzed the timespan from May 1 to June 19. The number of occasions a bear GPS collar detected a reindeer UHF collar from June 19 (day 50) and throughout the summer continued to lie between 0 to 10 occasions a day (mean = 4.9).

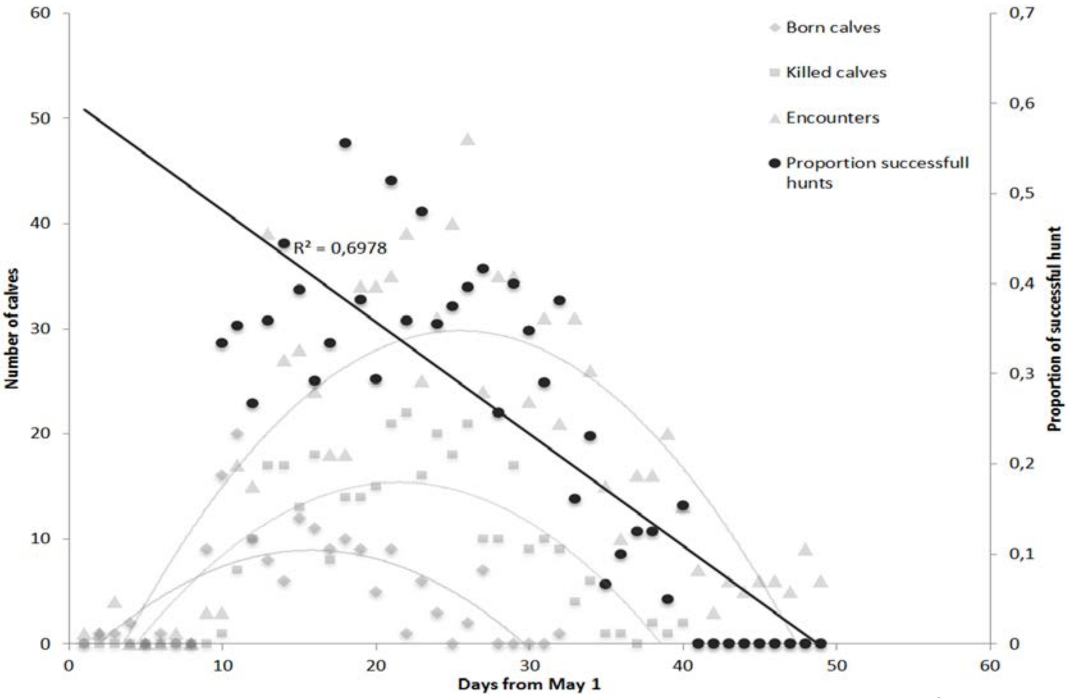

Figure 4: Hunting success shown in relationship to number of days from May 1 (R^2 = 0,698, p < 0.0001, n = 40).

DISCUSSION

The number of reindeer calves killed increased during the first 20 days from May 1 and then gradually decreased to 0, after 40 days. Moose calves (*Alces alces*), are another known prey for brown bears (Swenson *et al*. 2007; Kindberg et al. 2012). The predation periods differ when comparing brown bear predation on moose calves to that on reindeer calves. Predation on reindeer calves is mainly concentrated from the beginning of May to the beginning of June, whilst predation on moose calves mainly occurs during the period from the end of May to the end of June (Kindberg *et al*. 2012).

Studies on other large carnivores have shown that other factors such as snow depth, prey defense strategies, physical appearance of the landscape and individual characteristics of the predators can affect chase distances (Huggard 1993; Kauffman et al. 2007; Wikenros et al. 2009). Since reindeers are categorized as followers (Lent 1974; Rutberg 1984; Shackleton & Haywood 1985) they are therefore expected to use fleeing as an anti-predation strategy (Geist 1971; Lent 1974). This strategy relies on mobility for survival which suggests that it is an increased mobility (i.e. the ability to flee from predators) that is the mechanism behind the steep decline of hunting success shown in the results. This is supported by multiple studies showing that decreased vulnerability due to increased mobility is a mechanism behind bear predation patterns in ungulates (Bergerud 1971; Larsen et al. 1989; Adams et al. 1995).

I found no significant relationship between chase distance and number of days from May 1 ($R^2 = 0.024$, $p = 0.187$, $n = 75$). A possible explanation is that brown bears predate on reindeer calves of the same age (in this case < 8 days) and chase distance would then be expected to appear unchanged in relation to the number of days from May 1.

The lack of covariation between chase distances in relation to the length of the metatarsus can also be explained by that, in this study, bears predate on calves of an age up to eight days old, which would explain the lack of variation. The variation in metatarsus length, may in eight days, not have been large enough for us to detect any variation in length of the chase distance.

I found a significant negative relationship between the proportion of successful hunts and the number of days from May 1, when calving started. Encounters (i.e when a bear GPS collar detects a reindeer UHF collar) that results in a killed reindeer calf stopped completely eight days after the last calf was born. Some of the encounters were probably encounters where a bear and a reindeer passed each other without any interaction and the bears GPS got triggered. Visits in field during the predation study did prove that some of these continued encounters were in fact hunting trials. Therefore I suggest that bears continue chasing reindeer but cannot catch them due to their increased mobility.

Management implications

Modern Swedish reindeer husbandry is based on maximizing production (Danell 1999). Today this is obtained by the harvest of adult male reindeers in September and of calves in late autumn (Lundqvist 2007). The reindeer herds therefore mainly consist of fertile females and only a few males.

Neonates in ungulates are most vulnerable to predation the first month from birth (Bergerud 1971; Ballard et al. 1981; Zager & Beecham 2006; Swenson et al. 2007; Barber-Meyer et al. 2008; Blanco et al. 2011) and one study has shown that depredation on caribou calves mainly (85 %) occurs within eight days from birth (Adams et al. 1995). My results are consistent regarding time of predation compared to the above studies, since the killing of calves in my study ended eight days after the last calf was born. Consistency is also found between these studies and mine regarding the fact that predation by brown bear thereafter declines. One mechanism behind this pattern is presumed to be that the offspring becomes less vulnerable to predation with increasing age and mobility (Adams et al. 1995; Bergerud 1971; Ballard et al. 1981; Larsen et al. 1989; Karlsson et al. 2012).

A study on wild reindeer in Norway showed that the main calving period (where 90 % of all calves were born) for wild reindeer can be as narrow as 10 days (Holthe 1975). This is a good example of how ungulates use a synchronized calving period as an anti-predatory strategy to reduce predation on neonates (Estes 1976; Gregg et al. 2001; Testa 2002). This strategy narrows the window of opportunity for brown bear predation on reindeer calves. In the present study the main calving period was 18 days which is eight days longer than the study in Norway. Possible reasons for this might be sub-optimal herd structures, disturbances during sensitive periods such as rutting and calving periods, difficulties in keeping females in harems during rutting periods, sub-optimal areas used for calving and rutting periods as well as over-grazing and poor female condition.

Karlsson et al. (2012) showed that brown bears on average kill one calf every second day during the vulnerable period. For calving areas like the ones in this study, with >50 bears, the eight additional days (compared to the Norwegian study) would mean approximately 200 more calves killed. There is thus a potential for decreased calf losses due to brown bear predation by, if possible, narrowing the temporal window of opportunity.

One possibility to accomplish a more synchronized calving period is to optimize herd structure. If the proportion of males is too small to ensure mating of all (or most) females during the first rut, females will re-enter another oestrus cycle (Mossing & Rydberg 1982). With these later born calves, the window of predation for brown bear predation will then be open longer, thereby increasing the number of calves that are killed by brown bears.

A way to avoid this is to further optimize the proportion of male reindeers in the herd. The optimal proportion of males in the herd can be defined as the smallest number of males that can ensure impregnation without increasing the time of the calving period (Danell, pers. comm.). In practice, the optimal proportion of males differs between herds, but should have a proportion roof with an upper limit of 10 %, which one study has suggested in order to optimize slaughter yield (Danell 1999; Danell pers. comm.[1]). The age structure of males in ungulates has also been demonstrated to affect the calving period indirectly by influencing the rut period (Espmark 1964; Noyes 2002). Older reindeer males enter the rutting period earlier (Espmark 1964) and in elks, older males also have a shorter and more concentrated rutting period (Noyes 1996).

In Sweden the average proportion of males in herds were approximately 11 % in 2013 (Sametinget 2014). This indicates that there is an adequate proportion of males in the herds in Sweden. What then might be of interest is to look closer at the age structure of the herds. This would be in order to avoid having too young bulls or great variation regarding the age-span amongst the bulls and to ensure a synchronized entry to the first rutting period.

Minimizing disturbance during sensitive periods like the rutt and the calving season could possibly reduce the window of opportunity for predation. Most studies done on reindeer and disturbance before 1985 pointed out that effects on reindeer by human activities were short termed (reactions to stress lasted only for some minutes and fleeing distance were under one kilometer) (Vistnes & Nellemann 2007).

Reindeers may respond negatively to human activities (Wolfe et al. 2000) such as infrastructural work (Nelleman et al. 2001) and recreational outdoors activities (Reimers et al. 2006). Approaches on snowmobile have also been shown to cause disturbance (Tyler 1991), but the effects of this are not yet clear. This shows that not only human activities outside the reindeer husbandry but also the husbandry itself can cause disturbance when for example herders approach their reindeers using snowmobiles.

To avoid possible negative effects regarding, for example, the length of the calving season, the disturbance during sensitive periods for reindeers should be minimized (Wolfe et al. 2000). With disturbances during crucial stages in their life history, such as rutting and calving periods, one might expect it to affect the length of the calving season by disrupting the synchronization of rutting and thereby the calving period. That is, hinder a reduction of the window of opportunity. Another effect of disturbance by human activities has been shown to be avoidance of areas used by humans (Wolfe et al. 2000). Multiple investigations from 1990 and onwards show that caribou and reindeer in Arctic and sub-Arctic environments avoid areas with human disturbance such as roads, recreational resorts, pipelines and areas with logging operations (Vistness & Nellemann 2007).

In order to both avoid the risk that not all females are impregnated and to increase the possibility of having a more concentrated calving period, reindeer matings may be conducted in pens. If so, females will not be scattered over big areas and males do not have to waste energy by finding females to mate with. In the area of this study, 90-95 % of all females were pregnant but I do not know when the impregnation took place. Mating pens for reindeers has not, to my knowledge, yet been investigated, and I can only speculate on this method as a way to reduce predation.

Many studies show how female condition in reindeer and other ungulates are affecting gestation time and thus parturition dates and length of the calving season (Holthe 1975; Cameron et al. 1993; Adams & Dale 1998; Noyes et al. 2002). To ensure that all females in the reindeer herd are in good condition, supplementary feeding might be a solution. An equal and good condition amongst females within a herd should possibly lead to a more synchronized calving season resulting in a narrower window of opportunity for brown bear predation on reindeer calves.

More research is needed to find an optimal way to minimize losses of calves to brown bears, but apparently there are several possible solutions available. The two most feasible ways to accomplish a narrower window of opportunity for brown bear predation on reindeer calves seems to be: 1) to ensure that there is a large enough proportion of males in reindeer herds and; 2) to minimize disturbance during sensitive periods.

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